U.S. Fish and Wildlife Service
Fisheries Assistance Office
Olympia, Washington

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Port Angeles, Washington

Evaluation of Steelhead Smolt Survival through the Elwha Dams

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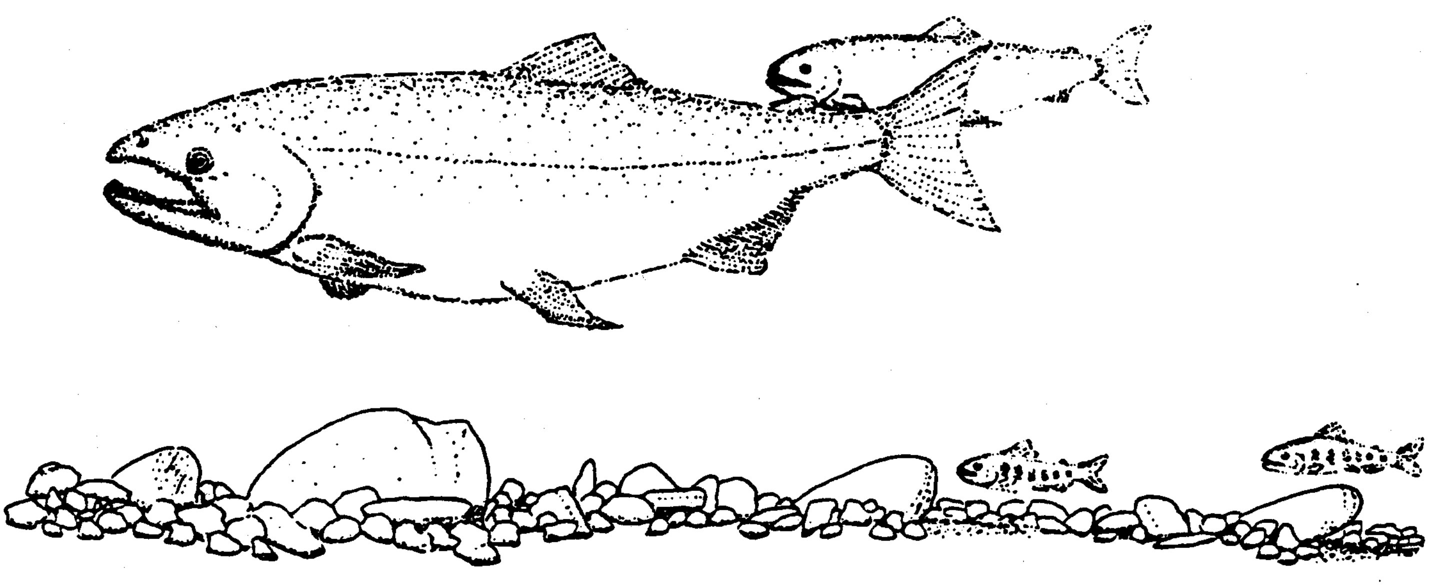

Evaluation of Steelhead Smolt Survival through the Elwha Dams

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ABSTRACT

We evaluated mortality of winter steelhead smolts passing the Elwha River dams. We released coded-wire tagged (CWT) test groups above the upper dam and CWT control groups below the lower dam in spring of 1986. We mark sampled the Elwha River sport and commercial steelhead fisheries over the winter of 1987-88 and recovered a total of 65 CWT adults from our 1986 releases. We computed survival rates of test and control groups and determined that 66% fewer test fish returned to the Elwha River. We attributed this difference to passage mortality. Using preliminary passage survival data from other evaluations at the Elwha dams, we estimated that about 14% mortality may have occcurred in passing the spillway at the upper dam, and the balance (52%) at the lower dam. Most losses at the lower dam probably occurred from turbine passage. Possible sources of estimation error are discussed. Results of this work are compared to a previous CWT evaluation of coho passage mortality at the Elwha dams.

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INTRODUCTION

In 1986, Fisheries Assistance Office (FAO) Olympia, in cooperation with the Olympic National Park and the Lower Elwha Tribe, began a study of juvenile steelhead trout passage at the Elwha River dams. Results of this study were intended for use in a larger effort involving assessment of the feasiblity of restoring anadromous salmonids, including steelhead, to the upper Elwha River basin above the Elwha dams. Development of effective fish passage measures at the Elwha River dams is necessary in this restoration effort, as no provisions currently exist to safely pass anadromous salmonids at these structures either on an interim or long-term basis.

The steelhead passage study described above involved two phases. The first phase, which occurred in 1986, involved analysis of steelhead smolt exit selection and rate of passage at Glines Canyon Dam. FAO released paired groups of coded-wire tagged (CWT) steelhead smolts above and below the Elwha dams (Figure 1). Downstream movement of test fish (those released above Glines Canyon Dam) was monitored hydroacoustically to assess exit selection and rate of passage in relation to spill at Glines Canyon Dam. The results of this work were described in an FAO report by Dilley and Wunderlich (1987).

The second phase of the study concerned evaluation of the effects of dam passage on long-term survival of steelhead smolts, and involved recovery and analysis of the coded-wire tags initially applied to the test and control groups in 1986. Recovery of the coded-wire test and control groups occurred in the lower Elwha River steelhead fisheries and hatchery rack during the winter of 1987-1988. This report primarily concerns the second phase of the steelhead passage study. We describe in detail the 1986 marking and subsequent recovery of the tagged steelhead groups in 1987-1988, and provide an analysis of dam passage mortality based on the tag recovery data. We also present incidental findings related to the tag recovery process and passage mortality evaluation.

METHODS

Marking of all test and contol groups occurred at the Lower Elwha Tribal Hatchery (Figure 1) using Elwha winter steelhead stock. On February 25th and 26th, 1986, we randomly seined fish from the tribe's production lot for processing through the FAO mobile tagging unit. We used only fish greater than five inches total length to help insure a target release size of approximately 5/lb, thereby reducing potential residualism. (This target release size followed Washington Department of Wildlife's (WDW) guidelines for fully smolted hatchery steelhead.) We based release group sizes on projected marine survival and river sampling rates that would yield at least 30 adult tag recoveries in the lower river fisheries and hatchery rack. Test group sizes were scaled approximately 1/3 greater than controls to offset anticipated mortality in dam passage. Each group received a unique mark using the CWT identification system (Bergman et al. 1968). Following CWT application, we placed each study group in a separate circular tank and adjusted the height of each tank's standpipe to maintain a uniform holding density of 0.5 lb/cu ft. We measured tag retention two weeks after tagging, and calculated tag group sizes by subtracting observed mortalities during tank holding from the number originally marked, then multiplying that value by the tag retention rate.

Our release strategy was intended to simulate passage mortality of naturally emigrating Elwha steelhead and, at the same time, minimize experimental design bias in this long-term passage mortality estimate. Each of the test and control groups was loaded into a tank truck and transported to the release site at a similar density. We released test groups at the boat ramp in the forebay of Lake Mills, as this was the highest vehicle access point in the upper watershed, and we released control groups at a vehicle access point near river mile 3 below Elwha Dam (Figure 1). Transportation to each site required approximately one-half hour. Four test/control pairs were released over the course of the expected natural emigration period. We delayed the release of control groups in each pair so both test and control groups would arrive at the estuary at approximately the same time. This was intended to minimize potential effects of differing saltwater entry on long-term survival, as had been observed in CWT-based studies of juvenile coho passage in the Elwha (Wunderlich 1988). Test fish delay was determined from ongoing hydroacoustic monitoring at Glines Canyon Dam (Dilley and Wunderlich 1987) and from previous observations of Elwha steelhead smolt movement (Wunderlich and Dilley 1986). Table 1 summarizes release information for the 1986 steelhead groups.

We expected coded-wire tagged study fish to return to the Elwha River in the winters of 1987-88 and 1988-89. Hatchery steelhead return chiefly as two-salt fish (after approximately one and a half years in the ocean) with the majority expected to return in 1987-88. We assumed that test and control fish would exhibit the same age distribution at return and, thus, survival comparisons could be made using two-salt fish only. Very few steelhead are caught in marine fisheries so sampling of adult steelhead in the river was expected to provide a good indication of relative survival of the various groups.

In addition to the test and control steelhead returning as part of this study, another group of adipose-clipped fish was expected to return to the Elwha River in 1987-88. These fish were released into the upper river above Lake Mills as fry in 1983. Only three-salt fish (and perhaps some repeat spawners) would return from this group in the winter of 1987-88. Although these fish were adipose clipped, they were not coded-wire tagged. However, they were differentiated from test and control fish using scale analysis to identify two years of freshwater rearing typical of wild steelhead.

Two river fisheries target on winter steelhead in the Elwha River: the Elwha Tribe's commercial gill net fishery and a recreational fishery. Elwha tribal fishing occurred on 33 days between December 14, 1987 and February 17, 1988. The fishery was open from the river mouth to the Highway 112 bridge.

Several fish buyers operated during the commercial season and our mark sampling was concentrated on those buyers handling the most fish. Sampling was conducted cooperatively by tribal and FAO technicians and was designed to meet the management needs of the tribe and this study. To meet the tribe's need of a random sample of biological information, every tenth fish was examined for scales, length, fin clips, and sex. To meet the needs of this study, all fish were examined for an adipose fin clip. The snout was removed from each adipose-clipped fish, labelled, frozen, and then shipped to FAO Olympia for standard tag removal processing. Biological information was also recorded. Scales collected from the commercial fishery were mounted, pressed, and then sent to WDW where they were read for hatchery or wild origin and age.

The Elwha River winter steelhead sport fishery officially opened on November 1, although few steelhead are normally caught prior to early December. The fishery remained open until April 15, 1988. Our sampling of the fishery began on December 5 and continued through April 9, 1988. Sampling occurred on 35 weekdays and 16 weekend days during the recreational fishing season. This sampling was not random to the extent that our samplers were directed to recover as many CWT fish as possible. Therefore, although they sampled the entire river normally accessible to fishermen, they concentrated on areas of the greatest expected catch and effort.

Snouts were removed from all sport-caught steelhead with adipose clips and biological information was recorded. Scales were mounted and sent to FAO for aging and identification of origin. The number of steelhead without adipose clips was recorded, but biological information was not collected from them.

Another area of potential tag recovery was the Elwha Tribal Hatchery. The test and control fish used in this study were reared at the tribal hatchery and released upstream. Although these fish would be expected to return to their upstream release sites, it would not be unusual for some to return to the hatchery. Tribal personnel examined all steelhead which returned to the hatchery rack for adipose clips. They also sub-sampled a portion of the returning fish for biological information.

Survival estimates for test and control groups were computed using both observed and expanded recoveries. In computing survival rates with observed recoveries, we assumed there were no differences in probable recovery rates between the test and control groups and, therefore, no need to expand the sample data to the entire catch. This assumption requires there not be any significant difference in timing or catchability between the test and control groups. Timing differences were examined using chi-square and the G test. Zar (1984) recommends use of the G test when the results differ from chi-square. Both tests were used in analyzing timing differences between test and control groups.

In estimating survival using expanded recoveries, it was necessary to use weekly and total catch estimates for the sport fisheries. Sport catch estimates were provided by WDW and are based upon voluntary returns of steelhead punch cards and a state-wide expansion factor. The expansion factor is estimated from punch-card returns and total catch in selected rivers where creel censuses were conducted. The Elwha River was not one of the rivers used to develop the expansion factor.

Expanded recoveries for the commercial fishery were estimated by dividing the number of sample recoveries by a preliminary estimate of daily catch. These preliminary catch estimates were provided by the Northwest Indian Fisheries Commission. Little or no change is expected between preliminary and final steelhead catch estimates from the Elwha River (Peter Dygart, Point-no-Point Treaty Council, pers. comm.).

Relative survival of test releases was computed by dividing their survival by the survival rate of the corresponding control group. Statistical significance of differences between corresponding test and control groups was evaluated by a procedure developed by Newman (1987). This procedure uses estimated tagged release numbers, expanded coded-wire tag recoveries, and estimated sampling rates to calculate a Z statistic. Unless otherwise stated, CWT-based survival values in this report refer to expanded survivals.

Wunderlich (1988) observed differences in lengths at adult recovery between test and control groups of coho passing the Elwha dams in 1984. We used analysis of variance (ANOVA) to determine if there were any differences in size of adult steelhead between test and control groups, by recovery periods, in this study.

We apportioned passage mortality between the two dams by independently calculating passage mortality for Glines Canyon Dam, then subtracting that value from the total CWT-based mortality estimate to arrive at an estimate of passage mortality for Elwha Dam. This approach assumed that latent mortality at the upper dam was insignificant. The independent estimate of Glines passage mortality was developed with a computer spreadsheet model using exit selection and short-term survival data collected in other FAO passage work at Glines. Estimated hourly movement of the CWT test groups through the spillway (gate 5) and turbine of Glines Canyon Dam (Figure 2) was available from the hydroacoustic data set collected in 1986 (Dilley and Wunderlich 1987). These turbine and spill exits were the only available means of downstream passage during emigration. Hourly movement values through these exits were adjusted to reflect expected survival under flow conditions existing at time of passage. Preliminary survival values used are shown in Table 2. (Turbine survival was estimated at 32% for all steelhead migrants. This value was based on available chinook survival data for the Glines turbine and may be higher than actually realized for steelhead; however, steelhead smolt passage through the turbine was virtually insignificant in 1986.) Adjusted hourly passage values were then summed over the total period of emigration to arrive at a steelhead mortality estimate for Glines Dam, which was subtracted from the total CWT-based estimate to approximate steelhead passage mortality at Elwha Dam.

RESULTS

A total of 509 steelhead were sampled in the Elwha Tribe's commerical fishery. Of this total, 219 were adipose clipped but only 23% (50 fish) actually contained coded-wire tags. Fourteen tags were from test groups released into Lake Mills and 36 were from control groups released at river mile three. Another 256 steelhead were sampled in the sport fishery, and seven adipose-clipped steelhead were returned voluntarily by sport fishermen. Thirty-seven of these fish were adipose clipped with 43% (16 fish) containing coded-wire tags. Nine of these tags were from control groups and seven from test releases. Appendix A and Appendix B list individual coded-wire tag recoveries from the commercial and sport fisheries, respectively.

The Elwha Tribe sampled 86 steelhead which returned to the hatchery rack. Only one was adipose clipped and it did not contain a coded-wire tag.

A difference in return timing for aggragated test and control groups was not apparent. The chi-square and G tests both indicated no significant differences ($P<0.05$) in timing of return.

Estimated survivals (to the Elwha commercial and recreational fisheries) for paired and aggregated test and control groups are presented in Table 1. Using aggregate observed recoveries, long-term survival for test fish was only 32% of that exhibited by control fish (Table 3). Long-term survival of test fish using the expanded data was 34% of that exhibited by the control groups (Table 3).

Newman's test indicated that differences in expanded survival between test and control groups were signficant for each test release except group number four (Table 4). This group was the last one released and had the lowest number of recoveries. The low number of recoveries possibly contributed to the lack of statistical significance in this comparison.

Biological information from the tribe's random sample of the commercial fishery is presented in Table 5. No adults exhibiting scale patterns characteristic of the 1983 fry plant into the upper river were noted in either the commercial or sport fishery. Steelhead in the random sample were chiefly hatchery fish, as expected, and comprised 92% of the sample. Only one repeat spawner was detected. However, the commercial fishery was not representative of the entire run since this fishery closed on February 17. The proportion of wild steelhead would be expected to increase toward the latter portion of the winter season.

Wunderlich (1988) found notable differences in mean length between adult (age 3) recoveries of test and control groups of coho smolts released into the Elwha River in a study similiar to this investigation. These differences were probably related to a delay of the test groups in Lake Mills and a reduced period of early marine growth. Although the test groups of steelhead used in this study did not experience extensive delays in exiting Lake Mills, we examined mean lengths of test and control releases using ANOVA. There were too few recoveries of some groups to compare fish lengths between paired releases. We aggregated the test and control groups and found a mean length of 64.8 cm and 65.7 cm, respectively. This difference was not statistically significant ($F=0.253$, $P<0.05$).

Of the total estimated passage loss of 66%, we attribute approximately 14% to Glines Canyon Dam and the remaining 52% of the loss to Elwha Dam.

DISCUSSION

We believe the main sources of passage mortality among steelhead smolts in 1986 were, first, the Elwha Dam turbines, then Glines Canyon Dam spillway passage, and last, the spillways of Elwha Dam.

We believe turbine mortality at Elwha Dam was likely the main source of loss for steelhead smolts in 1986 because of a high turbine passage rate coupled with a relatively high turbine kill rate. Hydroacoustic monitoring of coho and steelhead smolt movement through Elwha Dam in 1985 showed that nearly all migrants (approximately 95%) chose the turbine intakes (Figure 3), and that volume of spill was not a major influence in this choice (Wunderlich and Dilley 1986). During the 1986 emigration, substantial streamflow passed through the Elwha Dam turbines so it is likely that a similarly high passage rate occurred. Coupled with this high turbine passage rate is the likelihood of a relatively high mortality rate for steelhead smolts because of their size. The Elwha Dam contains Francis-style turbines, which tend to cause greater mortality with larger sized fish (Bell 1981, 1984). Previous studies of Elwha Dam turbine mortality have shown no loss for fingerling chinook (Schoeneman and Junge 1954), but approximately 10-30% mortality for larger coho smolts (Wunderlich and Dilley 1985). Steelhead smolts, being larger yet, would likely experience still greater mortality. In this study, it may have exceeded 50%.

We believe that estimated losses at Glines Canyon Dam (14% loss) resulted from substantial low-level spilling through gate 5. We know from the hydroacoustic passage monitoring in 1986 that virtually all migration occurred through this spillgate. Review of streamflow records during the passage period indicates that, indeed, approximately one-third of the spill days were at levels believed to be injurious to downstream migrants (less than 450 cfs spill as shown in Table 2). Our spreadsheet mortality estimate of 14% reflects this substantial degree of low-level spilling.

Figure 4 shows estimated daily migration and associated spill levels at Glines Canyon Dam during the passage period. As the figure indicates, generally higher spills occurred later in the passage period, so later migrating fish may have fared better. However, no clear trend is apparent in the relative survivals (Table 3). Expanded survival of the last CWT test group was relatively high compared to its control, but the difference was not statistically significant (Table 4). Some delay occurred between release of successive CWT test groups in Lake Mills (Figure 5), and this could have obscured survival differences among the four test groups. Additionally, test survivals could have been further affected by changes in generation level at the lower dam during emigration. Figure 6 indicates turbine generation (turbine flow) changes which occurred over the steelhead passage period. Bell (1981) indicates that changes in generation level of Francis-style turbines can affect fish survival, and Wunderlich and Dilley (1985) measured such changes in coho survival through the Elwha Dam's Francis turbines.

Migrant loss probably also occurred from spilling at Elwha Dam, but we expect such loss was relatively minor because of low movement through the spillways. Review of spill records at Elwha Dam showed spillage through both spillways (Figure 6). Spillage in the left spillway was at levels measured to be harmful to coho smolts in earlier tests at gate 3 (Wunderlich and Dilley 1985), and we expect that it was similarly harmful to steelhead smolts in 1986 which passed via gate 4. Spill through the right spillway was probably even more harmful because of the very roughened surface present (Wampler et al. 1985). However, as previously mentioned, we expect nearly all migrants passed via the turbines based on earlier monitoring studies of Elwha Dam passage (Wunderlich and Dilley 1986), thus avoiding substantial spillway mortality at the lower dam.

The overall loss estimate for steelhead in 1986 (66% mortality) is much greater than a comparable estimate of coho mortality in 1984 (Wunderlich 1988). In 1984, coded-wire tagged coho were released above and below the Elwha dams to estimate passage mortality, and recent analysis of the tag recovery data suggested only about 15% loss in passage. We believe that the greater mortality estimate for steelhead in this study resulted from higher turbine and spillway mortalities at both dams.

Comparing passage conditions at Glines Canyon Dam in 1984 and 1986 indicates that less low-level spilling occurred in 1984 than 1986, and this could have substantially benefitted survival of coho smolts. Flow records indicate that only about 12% of spill days in 1984 were at spills believed to be injurious to migrants, whereas about one-third of 1986 spill days were at such levels. We should note, however, that spilling in 1984 occurred at gate 3 instead of gate 5. We assume that low-level spills at gate 3 are equally harmful as at gate 5, but no specific measures of gate 3 survival are available.

Passage conditions at Elwha Dam were also probably poorer for steelhead smolts than coho smolts, primarily because of the greater size of steelhead and attendant higher turbine mortality in the Francis turbines of the lower dam. These turbines were likely the chief route of passage in both years. Mean forklength of steelhead test groups ranged from 195 to 203 mm versus only 128 to 141 mm for coho test groups in 1984. At similar generation levels, such differences in fish length can be a significant factor in fish survival through the Francis machine (Bell 1981).

The high proportion of adipose-clipped steelhead recovered without coded-wire tags was surprising. This could have resulted from a high incidence of tag loss after tagging, misreporting of catch locations in the commercial fishery, and/or hatchery strays from other river systems. Although FAO tag retention sampling was conducted sooner after tagging than usual, other aspects of this study's tagging operation proceeded normally. The fish were relatively large at tagging, which reduced the likelihood of tag loss. In addition, the FAO tag supervisor had extensive experience with coded-wire tagging and did not note any mechanical or other problems during the tagging process.

Some misreporting of commercial catches may have occurred. However, if misreporting was a significant contributor to this problem, the proportion of unmarked, marked, and tagged fish should have varied between fishery openings (Table 6). While there was a fairly high proportion of adipose-clipped fish on December 22 and 23, the percentages were relatively constant during the remainder of the season.

Straying of hatchery steelhead has been noted by other investigators. Hiss et al. (1986) found large numbers of stray hatchery fish in the Hoh River on the north Washington coast in 1984-85. Lirette and Hooten (1988) also estimated stray rates of up to 33% for off-station plants of steelhead smolts on British Columbia's Vancouver Island. WDW recently began adipose clipping hatchery steelhead smolts without coded-wire tagging them to manage for reduced wild fish harvest. The British Columbia Ministry of Environment and Parks is also adipose clipping hatchery steelhead. Table 7 presents the number of adipose-clipped smolts released into selected Vancouver Island, Puget Sound, Hood Canal, Washington coastal, and Strait of Juan de Fuca streams. Based on these data, we suspect hatchery strays contributed the majority of the untagged fish in the Elwha River during our sampling.

Release location of control groups was another factor potentially affecting recovery rates, although we suspect any such effect was minimal. Control groups were released at river mile three, and adult returns may not have ascended as far upriver as test fish due to differences in imprinting location. However, virtually all fishing effort occurred downstream of the control release point, so location of release should have had minimal effect on adult tag recoveries of study groups.

Survival back to the river for all groups was generally lower than expected (Table 1). CWT-based survival for three earlier brood years averaged 3.84%, but releases occurred downstream at the hatchery outfall. No comparable estimates exist for this brood year. Routine health inspections indicated no disease problems in the production lot used for this study (Ray Brunson, Olympia Fish Health Center, pers. comm.).

Some CWT test fish may have residualized (or died) in Lake Mills but the potential effect on our passage survival estimates was considered minimal. Approximately 93.2% of test fish were detected leaving Lake Mills during the hydroacoustic monitoring period (Dilley and Wunderlich 1987). If the entire undetected remainder (6.8%) stayed in Lake Mills, it would raise our final passage survival estimate for all CWT test groups only about 0.2%, and would not change our 34% survival figure when rounded to the nearest percentile (Table 3). Statistical significance would also not be affected. Because some delay in movement occurred between releases of successive CWT test groups in Lake Mills (Figure 5), we do not know whether any specific CWT test groups may have been more affected by residualism than others. However, even if all residualism occurred in only a single test group (which is unlikely), the maximum increase in survival for any given test group does not exceed 3% of the previously calculated values (Table 3) and statistical significance for each test/control pair remains unchanged.

SUMMARY

We estimate that approximately 66% of steelhead smolts passing the Elwha River dams in 1986 were killed in turbines and spillways at these structures. Using preliminary exit survival data from other FAO studies of the Elwha dams, we further estimate that approximately 14% of the total loss occurred from passage over the Glines Canyon Dam spillway. Most of the remaining mortality (52%) was believed to occur at the Elwha Dam turbines, although some mortality probably also occurred in the Elwha Dam's left and right bank spillways.

We based our 66% loss estimate on CWT recovery data from test and control groups of winter steelhead smolts released in the Elwha River in 1986. Four CWT test groups were released in Lake Mills and four corresponding control groups were released below Elwha Dam over the spring outmigration period. In cooperation with the Elwha Tribe, we mark-sampled the Elwha sport and commercial steelhead fisheries during the winter of 1987-88 and recovered a total of 65 coded-wire tags from our study groups. After accounting for sampling rate, we computed expanded survival rates for all groups which showed that, overall, test fish survival was 66% lower than control fish survival. This substantial difference in survival was statistically significant.

Our estimate of steelhead smolt mortality is much greater than a comparable estimate of coho smolt mortality, which indicated only about 15% passage loss through both dams in 1984. The most likely reasons for our higher steelhead mortality estimate are 1) streamflows during the 1986 emigration were generally lower than during the 1984 emigration, which probably increased spillway mortality at both dams, particularly Glines Canyon Dam, and, 2) larger steelhead smolts would likely experience greater mortality than coho in Elwha Dam's Francis turbines, which were considered the chief passage route at this dam in both years.

A greater-than-anticipated number of untagged, adipose-clipped fish was recovered in our mark-recovery sampling. We attribute this high number of untagged steelhead present in the lower river to straying from other systems, rather than deficiencies in the original study tagging. We base this explanation on the typically high degree of straying observed in neighboring systems, coupled with the high level of adipose-clipped steelhead planting which occurred in 1986 in the region.

Other factors potentially affecting this long-term passage survival estimate were examined and considered inconsequential. These factors included disease, residualism, and sampling error associated with differences in entry timing or catchability of CWT test and control groups.

ACKNOWLEDGMENTS

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Follow-up mark-recovery work and tag analysis were supported by Olympic National Park, Lower Elwha Tribe, and also by the James River Corporation, FERC license applicant for the Elwha River dams.

Brian Winter, former Elwha tribal biologist, helped coordinate the commercial fishery sampling, and we appreciate his assistance.

Lauren Dean assisted with data reduction and graphics, and we appreciate her contribution.

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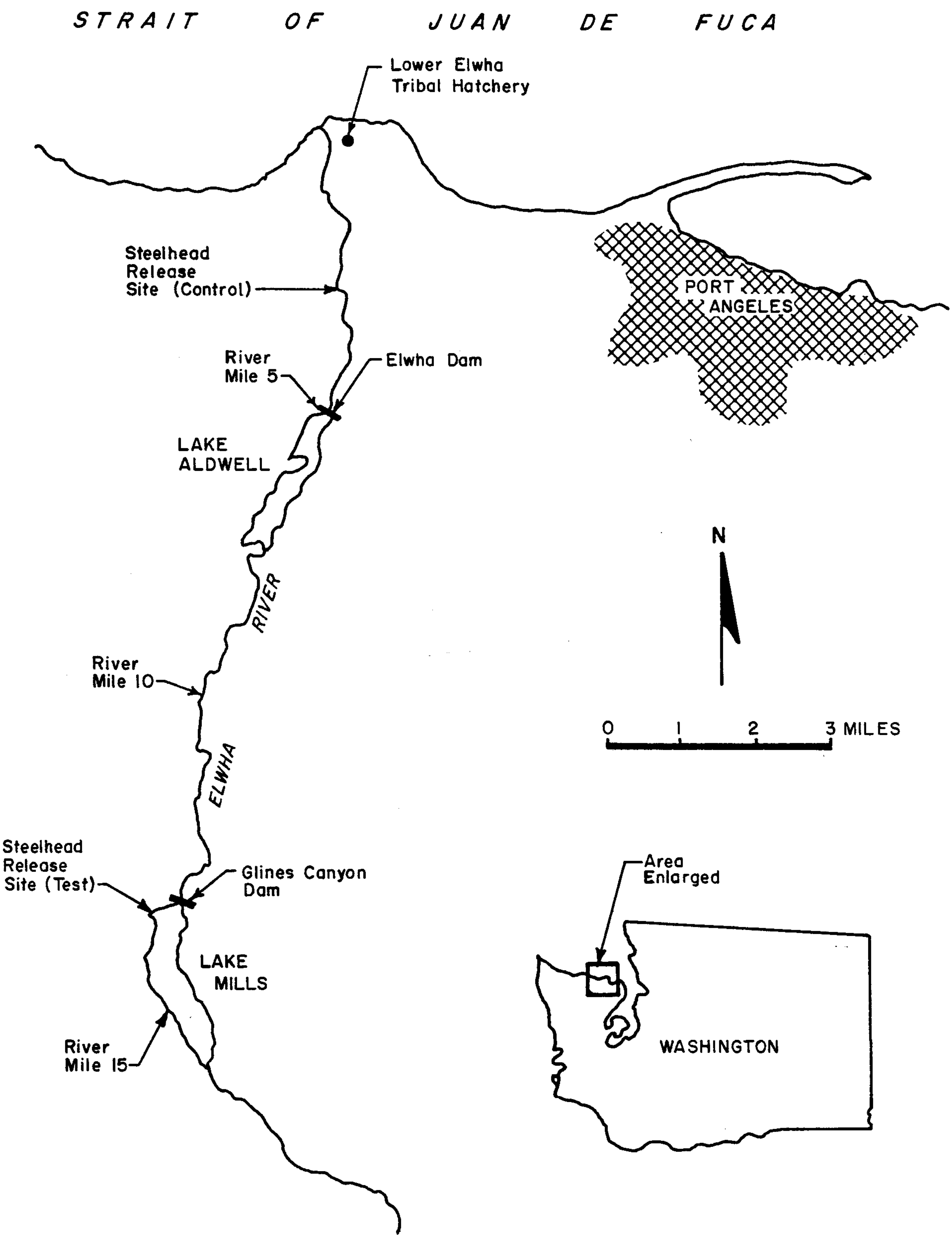

Figure 1. The Elwha River and project features.

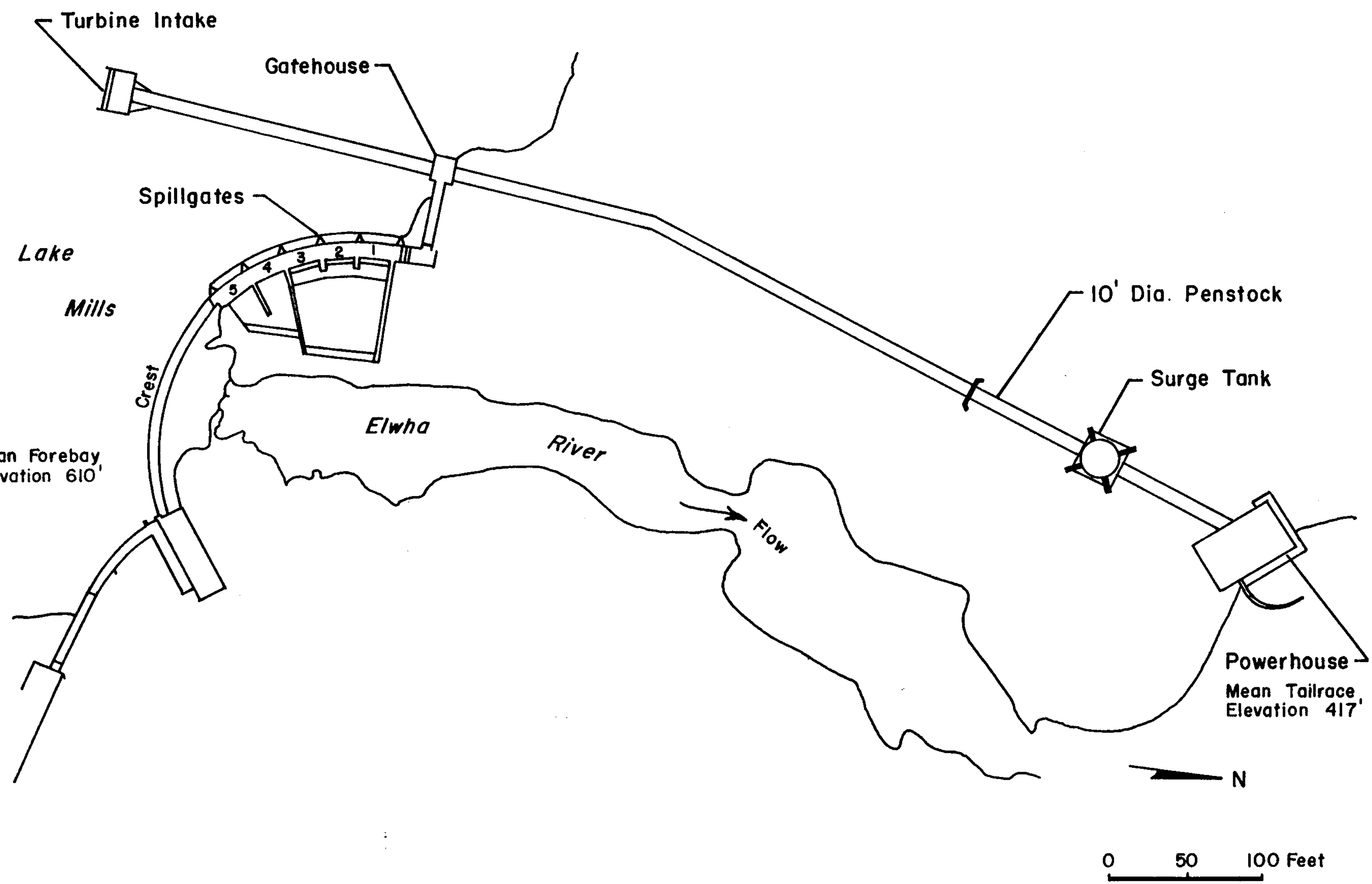

Figure 2. General features of Glines Canyon Dam.

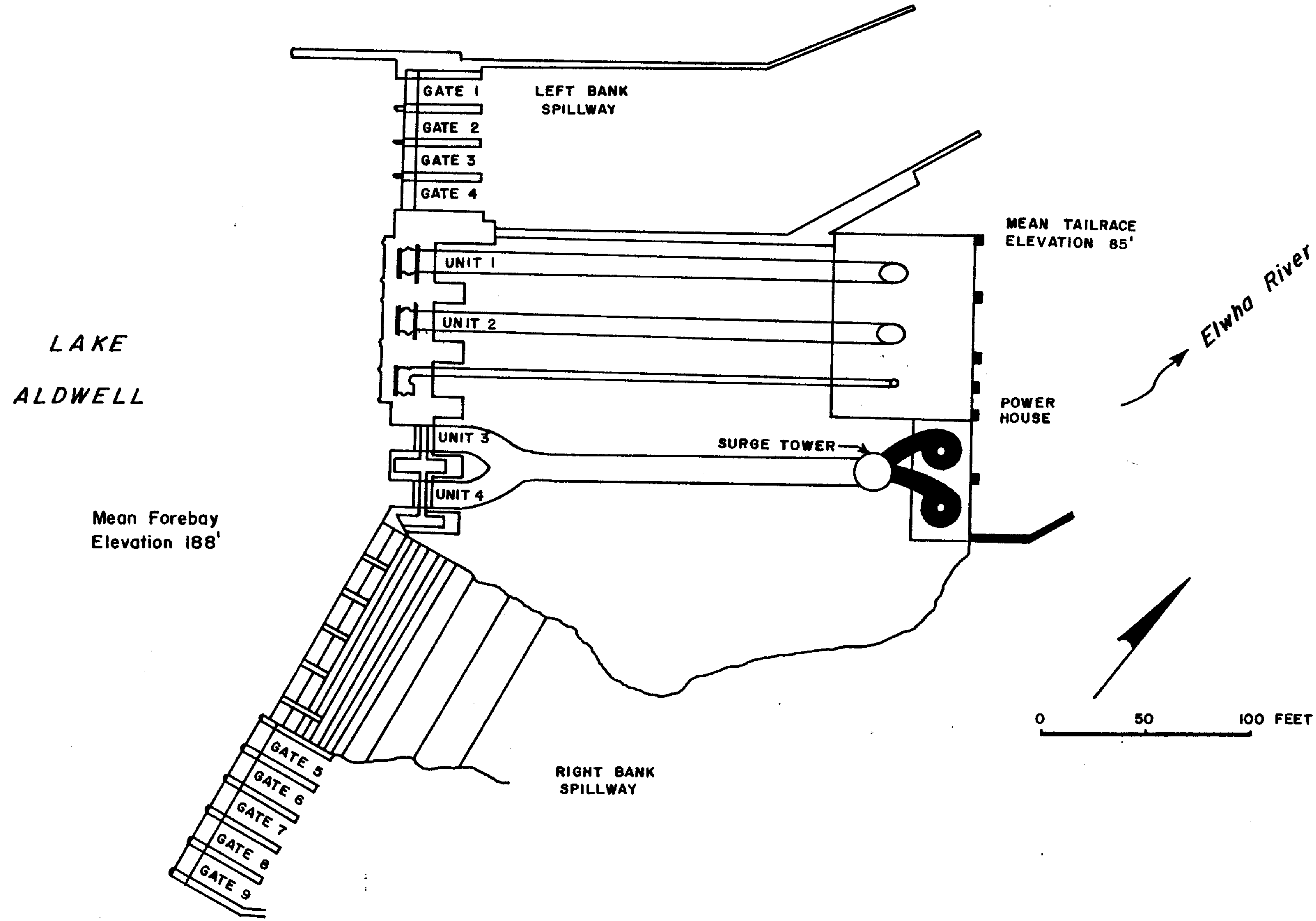

Figure 3. General features of Elwha Dam.

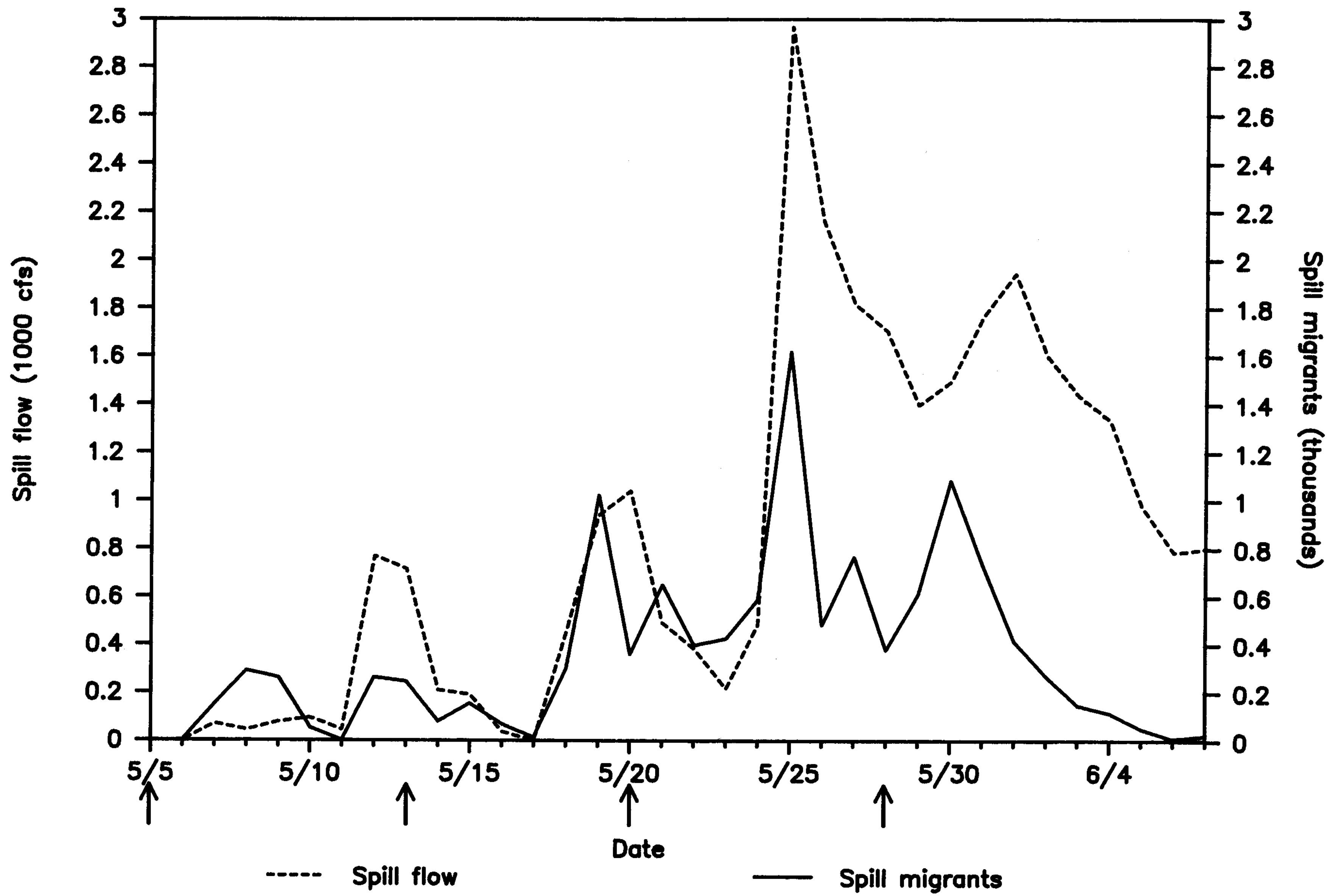

Figure 4. Estimated daily spillway migration and mean spillway flow at Glines Canyon Dam in 1986. Arrows denote release dates of the four CWT test groups.

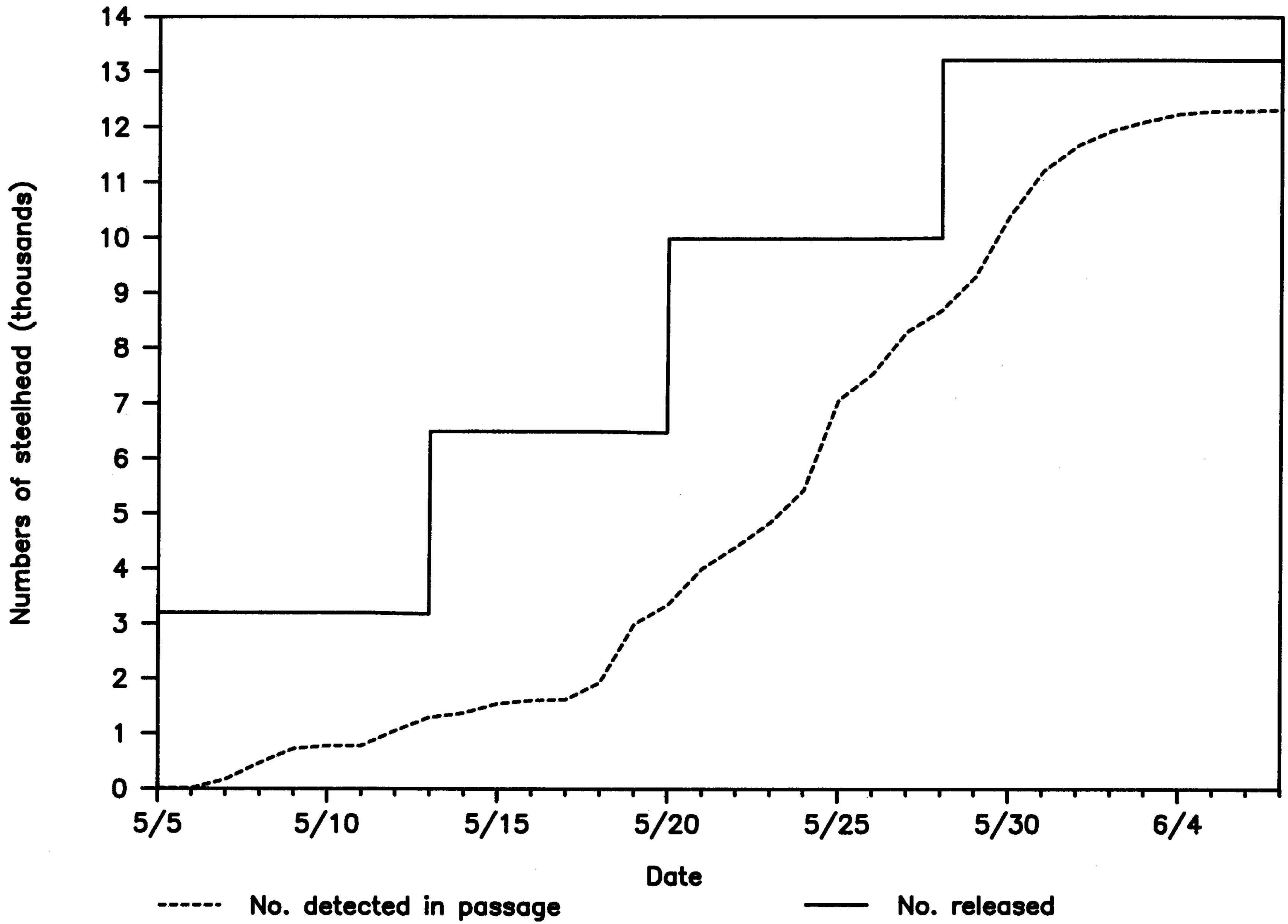

Figure 5. Cumulative numbers of steelhead smolts released in Lake Mills and detected passing Glines Canyon Dam in 1986.

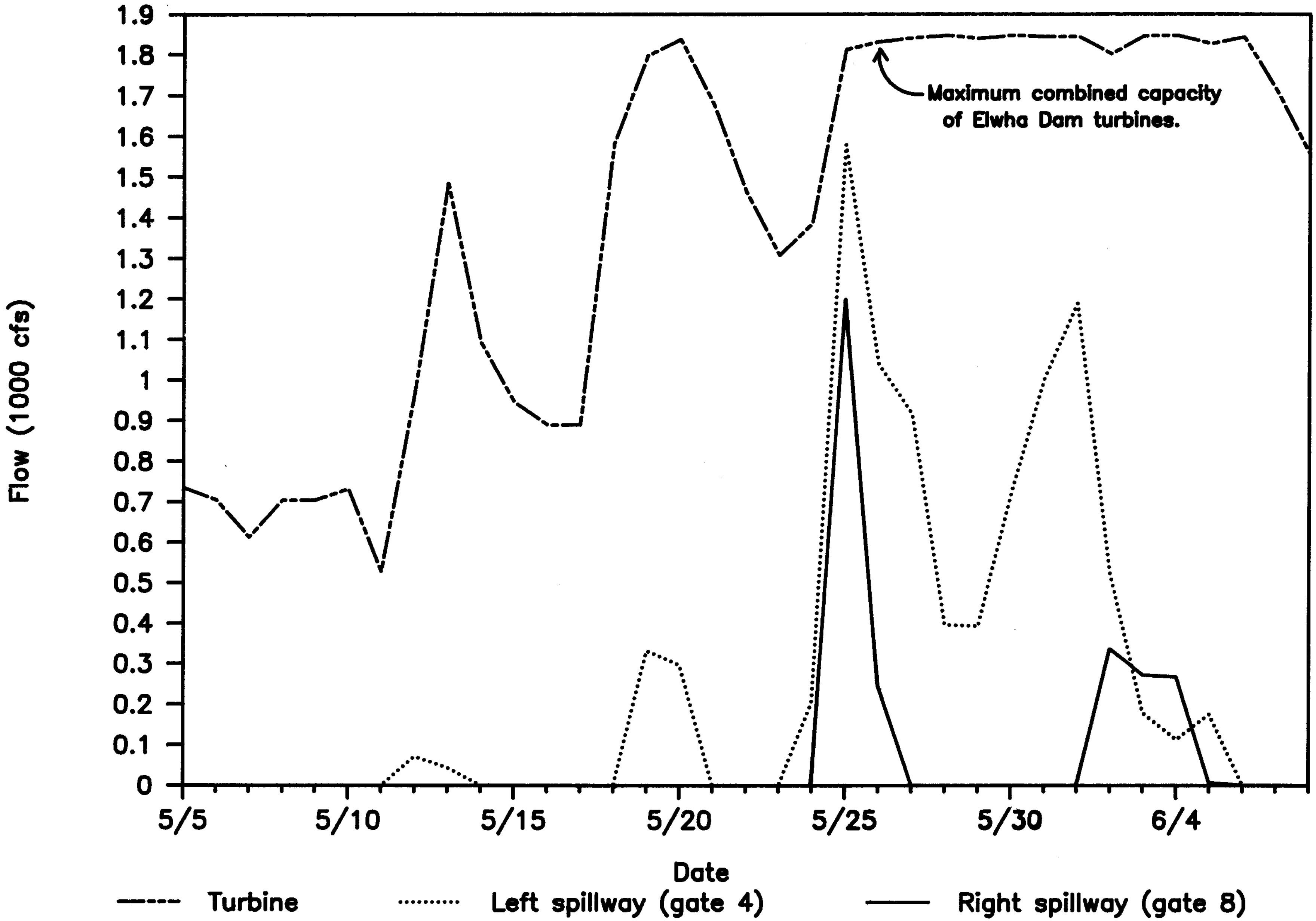

Figure 6. Daily turbine and spillway flow at Elwha Dam in 1986.

Table 1. Release and recovery data for Elwha winter steelhead smolts. Test groups were released into Lake Mills, and control groups at river mile 3, below both dams.

Release group	Release date	Tag code	Group size	Percent tag retention	Retention sample size	Tagged release	Mean fork length at release (mm)	Length sample size	Observed recoveries	Expanded recoveries	Expanded survival
Test no. 1	5/5/86	5-17-37	3,198	93.3	179	2,984	203	100	7	14	0.0047
Test no. 2	5/13/86	5-17-36	3,295	93.9	163	3,094	195	100	4	12	0.0039
Test no. 3	5/20/86	5-17-35	3,496	87.8	188	3,069	200	99	7	24	0.0078
Test no. 4	5/28/86	5-17-34	3,221	86.0	129	2,770	202	101	2	10	0.0036
Mean survival for combined test groups											0.0050
Control no. 1	5/7/86	5-17-33	2,415	95.8	192	2,314	199	99	13	30	0.0130
Control no. 2	5/22/86	5-17-32	2,379	89.8	128	2,136	202	100	10	35	0.0164
Control no. 3	5/28/86	5-17-30	2,297	83.7	123	1,923	203	100	14	42	0.0218
Control no. 4	6/3/86	5-17-31	2,233	92.1	139	2,057	207	99	8	16	0.0078
Mean survival for combined control groups											0.0146

Table 2. Preliminary spillway and turbine survival values for Glines Canyon Dam exits. These values are based on FAO survival studies conducted in 1987 and 1988 which are currently in preparation.

Exit	Exit flow	Estimated survival
Spillway[a]	< 250 cfs	0.35
Spillway[a]	250 - 450 cfs	0.50
Spillway[a]	> 450 cfs	1.00
Turbine	1100 cfs	0.32

[a]Spillway gate 5.

Table 3. Relative survival of the steelhead smolt test groups as compared to control groups. Relative survival was computed by dividing test group survival by corresponding control group survival and multiplying by 100.

Test group	Relative survival (observed)	Relative survival (expanded)
1	41%	36%
2	28%	24%
3	32%	36%
4	18%	46%
1-4 combined	32%	34%

Table 4. Statistical significance of survival rate differences between test and control groups.

Group	Expanded survival rate	Sampling fraction	Tagged release	Z statistic
Test no. 1	0.0047	0.5000	2,984	2.07^{a}
Control no. 1	0.0130	0.4333	2,314	
Test no. 2	0.0039	0.3333	3,094	2.26^{a}
Control no. 2	0.0164	0.2857	2,136	
Test no. 3	0.0078	0.2917	3,069	2.15^{a}
Control no. 3	0.0218	0.3333	1,923	
Test no. 4	0.0036	0.2000	2,770	1.12
Control no. 4	0.0078	0.5000	2,057	
All test	0.0050	0.3226	11,917	3.87^{a}
All control	0.0146	0.3629	8,430	

[a]Significant at 0.05 level.

Table 5. Biological information from the random sample of steelhead caught in the Elwha Tribe's 1987-88 commerical fishery.

	Percent of sample	Mean length	Age		Male	Female
			Two-salt	Three-salt		
Hatchery	92%	67.8 cm	.765	.235	.550	.450
Wild	8%	70.4 cm	.565	.435	.692	.308

Table 6. Percentage of adipose-clipped and coded-wire tagged steelhead in the Elwha River commercial fishery, 1987-88.

Date	Total catch	Number sampled	Percent adipose-clipped	Percent coded-wire-tagged
Dec 22	9	9	77.8	33.3
Dec 23	144	108	42.6	3.7
Jan 4	137	63	27.0	6.3
Jan 6	78	71	26.8	1.4
Jan 12	67	47	29.8	12.8
Jan 13	146	119	17.6	3.4
Jan 14	30	11	36.4	0
Jan 15	160	136	21.3	3.4
Jan 22	46	2	0	0
Jan 23	102	27	25.9	7.4
Jan 25	74	50	30.0	12.0
Jan 26	84	69	21.7	7.2
Feb 4	75	70	25.7	8.6
Feb 5	61	28	32.1	17.9

Table 7. Adipose-clipped steelhead from the 1985 brood year released in the spring of 1986 in nearby British Columbia and Washington waters.

Area	Stream	Approximate number
British Columbia[a]		
South Mainland Coast	Chilliwack	64,000
South Mainland Coast	Chehalis	59,000
Vancouver Island	Big Qualicum	28,000
Vancouver Island	Sooke	53,000
Vancouver Island	Cowichan	48,000
Vancouver Island	Nanaimo	38,000
Washington[b]		
North Washington Coast	Sooes	65,000
North Washington Coast	Waatch	10,000
Strait of Juan de Fuca	Clallam	10,000
Strait of Juan de Fuca	Dungeness	15,000
Strait of Juan de Fuca	Hoko	15,000
Strait of Juan de Fuca	Lyre	24,000
Strait of Juan de Fuca	Morse	19,000
Strait of Juan de Fuca	Pysht	10,000
Hood Canal	Dosewallips	20,000
Hood Canal	Duckabush	22,000
Hood Canal	Quilcene	10,000
Puget Sound	Skagit System	300,000
Puget Sound	Snohomish System	360,000

[a]British Columbia releases courtesy of Bryan Ludwig, B.C. Ministry of Environment and Parks.

[b]Washington releases courtesy of Terry Lougren, Washington Department of Wildlife.

Appendix A. Coded-wire tagged steelhead recovered from the Elwha Tribe's commercial fishery in 1987-88.

Year	Month	Day	Fork length (cm)	Sex	Tag code
87	12	22	69	Male	5-17-30
87	12	22	Unknown	Unknown	5-17-37
87	12	23	Unknown	Unknown	5-17-30
87	12	23	Unknown	Unknown	5-17-32
87	12	23	Unknown	Unknown	5-17-31
87	12	23	Unknown	Unknown	5-17-35
88	1	4	66	Male	5-17-30
88	1	4	64	Male	5-17-36
88	1	4	68	Male	5-17-33
88	1	4	63	Male	5-17-35
88	1	6	60	Male	5-17-31
88	1	12	60	Male	5-17-32
88	1	12	62	Male	5-17-31
88	1	12	66	Male	5-17-30
88	1	12	65	Female	5-17-30
88	1	12	64	Male	5-17-30
88	1	12	Unknown	Unknown	5-17-34
88	1	13	64	Male	5-17-35
88	1	13	60	Female	5-17-30
88	1	13	62	Male	5-17-31
88	1	13	Unknown	Unknown	5-17-35
88	1	15	68	Male	5-17-32
88	1	15	69	Male	5-17-33
88	1	15	66	Male	5-17-33
88	1	15	66	Male	5-17-33
88	1	15	62	Male	5-17-31
88	1	23	66	Male	5-17-33
88	1	23	64	Female	5-17-33
88	1	25	60	Female	5-17-32
88	1	25	70	Male	5-17-37
88	1	25	65	Male	5-17-32
88	1	25	73	Male	5-17-33
88	1	25	68	Female	5-17-37
88	1	25	60	Male	5-17-35
88	1	26	67	Male	5-17-33
88	1	26	64	Male	5-17-32
88	1	26	66	Male	5-17-33
88	1	26	68	Male	5-17-33
88	1	26	67	Male	5-17-31
88	2	4	63	Female	5-17-30
88	2	4	63	Female	5-17-30
88	2	4	64	Female	5-17-33
88	2	4	64	Female	5-17-36
88	2	4	67	Male	5-17-36
88	2	4	63	Female	5-17-37
88	2	5	60	Male	5-17-32

Appendix A (con't).

Year	Month	Day	Fork length (cm)	Sex	Tag code
88	2	5	68	Male	5-17-33
88	2	5	60	Female	5-17-30
88	2	5	73	Male	5-17-30
88	2	5	66	Male	5-17-30

Appendix B. Coded-wire tagged steelhead recovered from Elwha River sportsmen in 1987-88.

Year	Month	Day	Fork length (cm)	Sex	Tag code	Comments
87	12	26	72	Unknown	5-17-35	
87	12	26	62	Female	5-17-32	
87	12	26	70	Male	5-17-30	
87	12	30	Unknown	Unknown	5-17-37	Voluntary recovery
87	12	30	67	Female	5-17-36	
88	1	6	66	Unknown	5-17-34	
88	1	9	62	Female	5-17-32	
88	1	9	71	Male	5-17-30	
88	1	11	62	Male	5-17-31	Voluntary recovery
88	1	11	66	Female	5-17-33	
88	1	11	67	Male	5-17-37	
88	1	11	65	Male	5-17-35	
88	1	30	64	Female	5-17-32	
88	2	9	62	Female	5-17-30	
88	2	10	60	Female	5-17-31	
88	4	Unknown	67	Unknown	5-17-37	Voluntary recovery